WIND GENERATED ELECTRICITY
HISTORY AND ASSESSMENT

Prepared Pursuant To
Act No. 59 of the
1993 Vermont Legislature

Technical Report No. 30

January 15, 1994

Department of Public Service
120 State Street
Montpelier, Vermont 05620
(802) 828-2811
TTY/TDD (VT) 1-800-734-8390

TABLE OF CONTENTS

Acknowledgements

The Department thanks the following individuals and organizations for their contributions to this report:

James Fox, Morrisville Water & Light Department
Tom Gray, American Wind Energy Association
Tim Yarrow, Atlantic Orient Corporation
John Zimmerman, Vermont Environmental Resource Associates

Special mention is reserved for A. Norman Terreri of Green Mountain Power

INTRODUCTION

Public Act No. 59 of the 1993 Vermont Legislature, Section 26a, directed the Department of Public Service to coordinate a study of the use of wind power as a source of electricity. This document was prepared in response to that request. All the electric distribution companies in the state were contacted for input to the study. Green Mountain Power (GMP), Morrisville Electric Department, and Burlington Electric responded to that request.

Improvements in wind turbine technology and refinements in the techniques used to site wind machines make wind energy a realistic and environmentally sound technology to supply electricity to Vermont. Lack of large scale operating experience in New England climates makes precise cost estimates or construction goals difficult, however manufacturers and utility sources have estimated the costs to become competitive with conventional generation by the turn of the century. Evaluating the environmental impacts of alternative sources greatly improves the cost effectiveness of wind energy. While remaining concerns involving aesthetics and possible effects on bird populations require diligent work to overcome, the developable wind resource in Vermont has the potential to supply several percent of the state's electrical energy needs. If one includes the possibility of out of state purchases, this potential increases to 5 - 10%.

I. HISTORY: 1970 to DATE

A. California

Wind power experienced a boom period in California during the late 1970s. Substantial state tax credits combined with Federal grants convinced many small investors to set up wind energy ventures. Both the wind farms producing the energy and the manufacturers developing the hardware were small companies with limited resources. Unfortunately, many of the wind farms started during this time period were ill advised and poorly managed. Wind turbine design and the problems of harvesting wind for energy had been poorly understood and underestimated. Many of the wind turbines built were prototypes and were expensive, performed poorly, and were unreliable. Even with the substantial Federal and state tax credits, many of the early ventures were not competitive with alternatives. As a result wind power gained a poor reputation for quality and usefulness.

However, the pioneering efforts of California with wind power proved to be a valuable learning experience. There are now over 16,000 wind turbines in service in the US, with nearly all of them located in California.

In 1985 the Federal tax credit system was changed and in 1986 California ended it's tax credits for wind power. As a result, many wind farms went out of business. However, by this time substantial improvements in technology enabled the better sited, engineered and managed wind farms to survive. Contributing to this was California's Standard Offer 4 program which guaranteed a minimum price for wind energy. In fact, 450 MW of turbines

were financed after 1986, and wind energy production rose annually in California throughout the decade. (See Figure 1.) There are now more than 15,000 wind turbines operating in California.

B. Vermont History

Vermont was the site of one of the most ambitious early attempts made in America to harness the wind's energy potential. In 1941 the Smith-Putnam wind turbine was erected on Grandpa's Knob near Rutland. Given the state of wind technology and manufacturing technology in general, this was indeed a significant undertaking. The 1,250 kW turbine, however, produced only about 30% of its expected output. In 1942, a main bearing failed and because of the war it took two years to obtain a replacement. In 1945, one of the blades broke and the project was abandoned. Poor site selection, due to inaccurate wind measurement at the site, lack of replacement materials due to World War II shortages, and the lower cost of alternative power sources doomed the project.

The next attempts at generating wind power in Vermont occurred during the late 1970s and early 1980s. These efforts might be considered as failures. Much of the equipment set up to measure wind strength was stolen, vandalized or proved unable to survive the harsh Vermont weather. Several turbines were installed under a DOE program - one in Morrisville ant the other at Vermont Technical College. Ultimately these proved unreliable and were abandoned. Very little tangible value came of these initial efforts.

In 1980 and 1981, WTG Energy of Buffalo, NY, erected four 200 kW wind turbines on land owned by the Carthusian Foundation on a ridge on Equinox Mountain in Manchester. The output was sold to Central Vermont Public Service Company (CVPS). These machines operated sporadically, and were frequently down for maintenance. By the mid 1980s they were all out of service and had been removed from the site. In 1991, Green Mountain Power took over operation of this site as part of its wind development activities which are discussed more fully below.

C. New England History

In 1984, the town of Princeton, MA, voted to install 8, 40 kW wind turbines. The town load was 3 MW. Princeton Municipal Light Department (PML) thereby became the first utility to own and operate a wind farm. Within the first month of operation the manufacturer of their turbines went out of business. The four person staff of PML persevered and have operated their turbines successfully in all types of weather. The turbines now provide 10% of the energy needed by the town of Princeton. Until recently, this was the largest wind farm in the United States outside California. It remains the largest wind farm East of the Mississippi River. Within a decade PML managed to retire the debt on the turbines. Although it has received very little publicity, it is perhaps the greatest success story outside of California.

II. WIND POWER IN THE 1990s

A. United States Progress

Throughout the 1980s wind turbine developers steadily improved the performance of their machines to the point where recent bid proposals are offering contracts at less than 5 cents per kWh for the mid-1990s. Utility companies are gradually changing their negative view of wind power. However, even though some utilities have recently signed agreements to construct wind generating stations, there are currently only a handful of small utility owned wind farms in operation. Most existing machines are owned by independent power producers who are selling electricity under the federal Public Utilities Regulatory Policy Act (PURPA) which required utilities to purchase power from independent power producers.

Advances in turbine performance and increased environmental awareness have fueled a resurgence of interest in wind energy systems. Wind energy costs have decreased significantly since the early 1980s. The U.S. Department of Energy has estimated that the cost of wind generated electricity is between 4 and 7.5 cents per kWh and declining in real terms. (See Figure 2.) Due to a lack of experience with wind technologies, at this time there is no accepted way to assign a capacity value to a wind development in the way capacity can be credited to a combustion plant. As members of New England Power Pool (NEPOOL), Vermont utilities are required to purchase and maintain capacity to meet their responsibilities within the pool. Any capacity ultimately credited to wind machines will increase their value. The cost of the electricity generated by a wind turbine is also critically dependent on the wind speed of the chosen location. As a rule of thumb, the cost of the electricity increases by about 1 cent per kWh for every 1 mph decrease in the average wind velocity. This makes micro siting and the development of techniques to accurately site wind turbines of vital importance.

In 1992, President Bush signed the Energy Policy Act which gives a 1.5 cent per kWh tax credit for all output from wind turbines built between January 1994 and June 1999. This incentive has encouraged utility companies to reexamine wind power. Utility companies, which are normally conservative in nature, have begun to invest directly in wind turbines.

The American Wind Energy Association is proposing that utilities, industry and government form a collaborative partnership with a goal of installing 10,000 MW of wind turbines in the United States by the year 2000. The federal government has committed support to aid in the formation of this partnership. Most observers, including the DPS, view this goal as very extreme. It does serve, however, to highlight wind energy as an attractive option for this decade. A key barrier is lack of adequate site specific wind data. This goal serves to motivate utility and non-utility firms to collect the necessary data. On another front, the Electric Power Research Institute and the United States Department of Energy have co-sponsored the formation of the Utility Wind Interest Group. Green Mountain Power is a founding member of this group and is represented on its Board of Directors.

Although 14 states have wind energy potential equal to or greater than California, until recently there has been little effort outside California to harness wind power for electricity needs. In 1991, California turbines generated 2.7 billion kWh of electricity, compared to 50 million for the rest of the U.S. Success in California has encouraged many utilities

elsewhere to begin developing projects alone or in joint ventures with other utilities or private developers. They include: Northern States Power Company, Puget Sound Power and Light, the Bonneville Power Administration, Pacific Gas & Electric Company, Niagara Mohawk Power, Iowa-Illinois Gas and Electric Company and Vermont's Green Mountain Power.

B. European and Canadian Progress

In 1992 European nations erected 400 MW of wind turbines in contrast to the 5 MW installed in the U.S. They are popular in Europe for the same reasons as the U.S. - the improving economics coupled with a desire or obligation to reduce CO^2 emissions or other environmental constraints. (See Figure 3.) Government support of wind power is also very strong in Europe. The European Community is providing financial support to nations desiring to undertake expansion of their wind resources. Their goal is to install at least 4000 MWs of wind power by the year 2000. Additionally, Hydro-Québec has recently committed to $100 million investment in wind generation by the turn of the century.

III. WIND POWER AND VERMONT'S FUTURE

One view of Vermont wind power comes from a 1991 report by the U.S. Department of Energy which estimated that Vermont has a theoretical wind energy potential of 537 equivalent MW, enough to satisfy 99% of electrical energy needs statewide.[1] [2] Unfortunately, many potential sites are currently not economic or are not practical to develop due to site constraints or aesthetic concerns. A recent estimate by Green Mountain Power of the available sites puts the in state potential between 50 and 100 MW of installed capacity.

A. Green Mountain Power Development Efforts

Of the Vermont utilities, Green Mountain Power has taken the most active role in the development of the state's wind resource potential. Research and development for GMP's current wind energy program began in 1978 with the installation of wind measurement equipment at a site overlooking Lake Champlain in Charlotte, Vermont. Results of this early research indicated only marginal wind conditions exist in the Champlain Valley and since that time the Company's focus has been on the more windy summits and ridges of the Green Mountains. Since the early 1980s, wind measurements have been made at ten potential site areas in Vermont. using more than 25 measurement locations. Data collected

---

[1]Elliott, D. L. et al. "An Assessment of the Available Windy Land Area and the Wind Energy Potential in the Contiguous United States." *Pacific Northwest Labs Report* PNL-7789 (August 1991).

[2]"Equivalent" MW refers to the number units that would be required to produce a certain amount of energy if they had sufficient wind available to operate at full power all the time. Actual units operate at much lower capacity factors so many more MW of turbines would actually be needed.

from GMP's efforts represents the most comprehensive wind power database in the eastern United States. The Company has more than 50,000 hours of data on wind conditions. Data also has been collected at other sites, and wind data from other sources that was collected at various locations in Vermont has been analyzed by GMP.

Since 1989, GMP has operated two experimental turbines on top of Little Equinox Mountain in Manchester. This is a site originally developed, unsuccessfully, by a private developer based in Buffalo, N.Y. GMP, working with the Carthusian order, which owns the land, took over the wind generation site and redeveloped it. The renovation included building new towers and installing new, state-of-the-art turbines.

The Mount Equinox turbines have operated steadily since December 1989. Three basic conclusions have been reached so far:

1. Wind generation, sited well and using high-tech equipment, is more efficient than had been projected for this climate.

2. Extremely cold weather does create special problems for wind generation equipment, but these problems are not overwhelming.

3. Public acceptance of wind generators, despite aesthetic concerns, is very high as long as the wind machines are operational; the public does not like wind power sites that are idle and therefore not contributing to the energy needs of state.

B. The Current Situation at Green Mountain Power

GMP is seeking permits to develop a wind generating facility in southwest Vermont, using two adjacent sites in Searsburg and Readsboro. These are among the sites the Company has been evaluating for more than a decade, and are considered to be among the best potential wind sites in Vermont

This will be the first commercial-scale, utility-owned wind generating station in the United States. It will have a minimum capacity of 6 MW, using at least 20 turbines. The project will use the latest generation of wind machines, possibly using several different designs.

In nationwide competition, GMP has won a $3 million grant for this project, half from the United State Department of Energy and half from the Electric Power Research Institute. GMP's share of the project cost is estimated to be approximately $9 million.

GMP is now proceeding through the federal and state permitting processes, with construction scheduled to begin early in 1995 and commercial operation expected before the end of 1995.

The cost of the power from this project is expected to be slightly higher than competitive sources of power at the outset but less expensive over the long run. The $3 million grant will make the project economically viable now according to GMP. The Company expects this project will yield a wealth of information on the viability of, and potential for, commercial-scale wind generation in Vermont and in the U.S.

IV. THE FUTURE

Vermont has a multitude of potential sites for wind facilities, but most of them are not considered suitable for development because of environmental considerations. The ridgetops of the Green mountains offer the best sites, when only the wind resource is considered, but they also are ecologically fragile and anesthetically sensitive locations. The environmental sensitivity of the highest (and windiest) ridge lines exclude most of them from development.

Many of the more remote sites are handicapped by the need to construct long stretches of transmission line to get the power into the Vermont grid. While the remote ridges have fewer environmental obstacles, their inaccessibility increase the cost of wind power because of higher construction and maintenance costs, in addition to the higher transmission costs. This illustrates two distinct visions for developing wind power in Vermont. The first would focus on developed areas. Aside from lower transmission and operating and maintenance costs, this approach constrains development to existing growth areas consistent with the goals of Act 200 and avoids unspoiled territory. The second would put wind turbines out of sight in remote areas. It is likely that Vermont will see proposals articulating each of these visions.

Based on preliminary surveys of sites known to offer good potential for wind generation, GMP estimates total potential in Vermont is greater than the state's total electric load of roughly 1,000 MW. Of the total potential, all but 50-100 MW is considered undevelopable for environmental or economic reasons. However, the operation of the 6-8 MW Searsburg-Readsboro facility will provide the experience necessary to refine the projections of wind potential.

V. THE WIND INDUSTRY IN VERMONT

Vermont is home to three wind energy related businesses. Together they employ about 70 people and have approximately $7 million in annual sales. Northern Power Systems in Moretown has worked with the DOE wind energy program to develop several high reliability wind machines used mainly in remote applications. They are currently working to develop village power systems for communities world wide by integrating wind, solar, micro hydro and diesel power systems. They are developing a 250 kW turbine which is aimed at the utility market.

NRG Systems of Hinesburg manufactures equipment and software for wind energy site evaluation. In the last year they reported an increase in business from utility customers seeking to evaluate potential sites in their service territories.

Atlantic Orient Corporation is located in Norwich. They manufacture a 50 kW turbine that could be used in utility applications or as power for commercial and industrial facilities.

These Vermont business are in a position to profit should there be an increased interest in wind energy installations from the utility industry.

VI. THE BENEFITS OF WIND POWER FOR VERMONT

Wind is a renewable resource. Unlike fossil fuels it will not run out or increase in price in the future. It will reduce America's need for imports to fuel its energy needs.

Wind power creates no air pollution. It doesn't use any fuel and therefore produces no air emissions. Use of wind to supplant combustion sources will mitigate the effects of acid rain and greenhouse gases. It has been estimated that in 1992, California's wind turbines reduced the generation of sulfur oxide and nitrous oxide by 13 million pounds.

Gaining experience with this and other renewable technologies is an important strategy to minimize risks associated with our current reliance on combustion sources. There are circumstances, possibly resulting from environmental or price concerns, which could result in a need for rapid repowering of New England. An example of this is the recent concern being expressed by insurance companies regarding the effects of greenhouse gasses and global warming. Experience gained in developing alternatives power sources will prove invaluable should such a situation arise.

Costs for wind power have fallen annually and should continue to fall due to improvements in technology. Figure 4 compares the costs of wind generated electricity to the Vermont statewide avoided costs. If one monetizes the external costs of the air emissions from the energy that is not produced as a result of operating the wind turbines in the NEPOOL system, the comparison is much more dramatic.

Winter produces the greatest amount of wind in Vermont, corresponding to the time of greatest need. Vermont's energy needs peak in the winter. In fact it is often cold, windy conditions which cause the greatest demands for electricity. This coincidence of supply and demand means that wind turbines should be operating at substantial rates during the times of greatest need, thereby supplanting the most expensive alternate energy.

VII. MAJOR CONCERNS REGARDING INCREASED WIND DEVELOPMENT

Aesthetic impacts are an important concern. To be effective, turbines must be placed at topographically prominent locations. Many times these are visually prominent locations as well. (See Figure 5 for artists rendering of GMP's proposed installation in Searsburg.) Some people find wind turbines to be visually unattractive. On the other hand others find them to be inspiring. While there is no easy answer to this issue, it points out the need to proceed with caution when siting new systems. Gaining the approval of all the interest groups in advance is especially important in pursuing this development. Adverse public reaction can tarnish the reputation of wind power, making further development much more difficult.

Most of the operating experience with wind turbines comes form the California installations. The climate of Vermont and its wind regimes are much different and the longevity of this technology has yet to be established for the Northeast. Green Mountain Power's work at the

Equinox site has provided valuable learning experience in operating a turbine in New England. The lessons learned here will be applied to any full scale projects.

Although the new technology being developed by the industry is promising, it has yet to be tested on a large scale. The major development heralding the new generation of turbines is the ability to operate at variable speeds. This innovation will allow turbines to more fully utilize the available wind energy. However, this technology has yet to be deployed in a commercial operation. (See Figure 5.)

Regulators need reliable information regarding the performance of turbines in order to make informed decisions regarding their installation.

There may be a conflict between the long term value of developing these renewable resources and the short term rate impacts that could be required to develop this technology.

Accurate valuation of wind generation depends, in part, on calculating its contribution to meeting peak power demand. The utility industry currently applies little or no capacity value to wind systems because the power may not be available at peak hours. This may, however, be an incorrect conclusion and this convention may change with more data and experience.

Because of the nature of the wind resource, the most desirable sites are often located on mountaintops in fragile ecological areas. More needs to be understood regarding the impacts of wind machines on the surrounding terrain and ways to mitigate these when they might occur.

The wind turbine manufacturing industry is still populated by small companies. While this is understandable, given the historical demand for their products, the status of the industry may give normally conservative utilities and regulators second thoughts regarding the security of investing with such companies.

Some wind farms in California have experienced problems with bird fatalities. Prior to 1989 there were no problems. However, in that year several dozen dead hawks and eagles were found beneath turbines in the Altamont Pass in California. So far this has been the only site to have this problem and it may be due to specific local conditions. However, wind developers must devote significant time and resources to characterize this issue in permitting.

The metal components of turbines can interfere with television and communication signals. This problem has been reduced by replacing the metal with composites, laminates and other synthetic materials where feasible.

Early turbines designs were noisy and contributed to noise pollution, however newer blade design have significantly reduced the amount of noise.

The energy produced by wind machines cannot be stored. It must be used at the time it is produced. This factor ultimately will limit the amount of wind energy which is practical to absorb in any power system.

VIII. SUMMARY

While the wind industry is facing significant obstacles in developing its technology, the experience gained to date and the improvements made have shown that this industry can respond to issues as they arise. The task remains to put these machines and other renewable technologies into utility operating systems in significant quantities to be able to accurately quantify their benefits.

The industry is working on technical developments to increase the production and reduce the cost of its machines. These same improvements will also make it economically viable to erect turbines in areas with lower average windspeeds. This improvement should open more terrain for wind development, an especially important consideration given the sensitivity of many of the prime wind sites.

As the electric utility industry and its customers are required to mitigate the impacts of fossil fuel generation, wind and other renewable technology, along with efficiency options represent environmentally sound alternatives. Failure to gain experience with these technologies at this time could produce significant consequences should a rapid switch to renewables be necessitated by some unexpected environmental or political events.

IX. RECOMMENDATIONS

Vermont should encourage timely development of renewable energy systems, including wind systems.

During the upcoming hearings to develop a new procurement system for independent power producers (Rule 4.100), the concerns relating to wind power should be addressed by the Vermont Public Service Board. Specifically, provisions should be developed to relate the capacity requirements listed for various classes of producers to wind energy installations.

The State's policy concerning environmental externalities should ensure that the true economic and environmental costs of generating electricity from all sources are fully incorporated into utility decisions.

If necessary, the Public Service Board should consider establishing a required minimum procurement of wind energy systems or other renewable energy generating sources by instate utilities

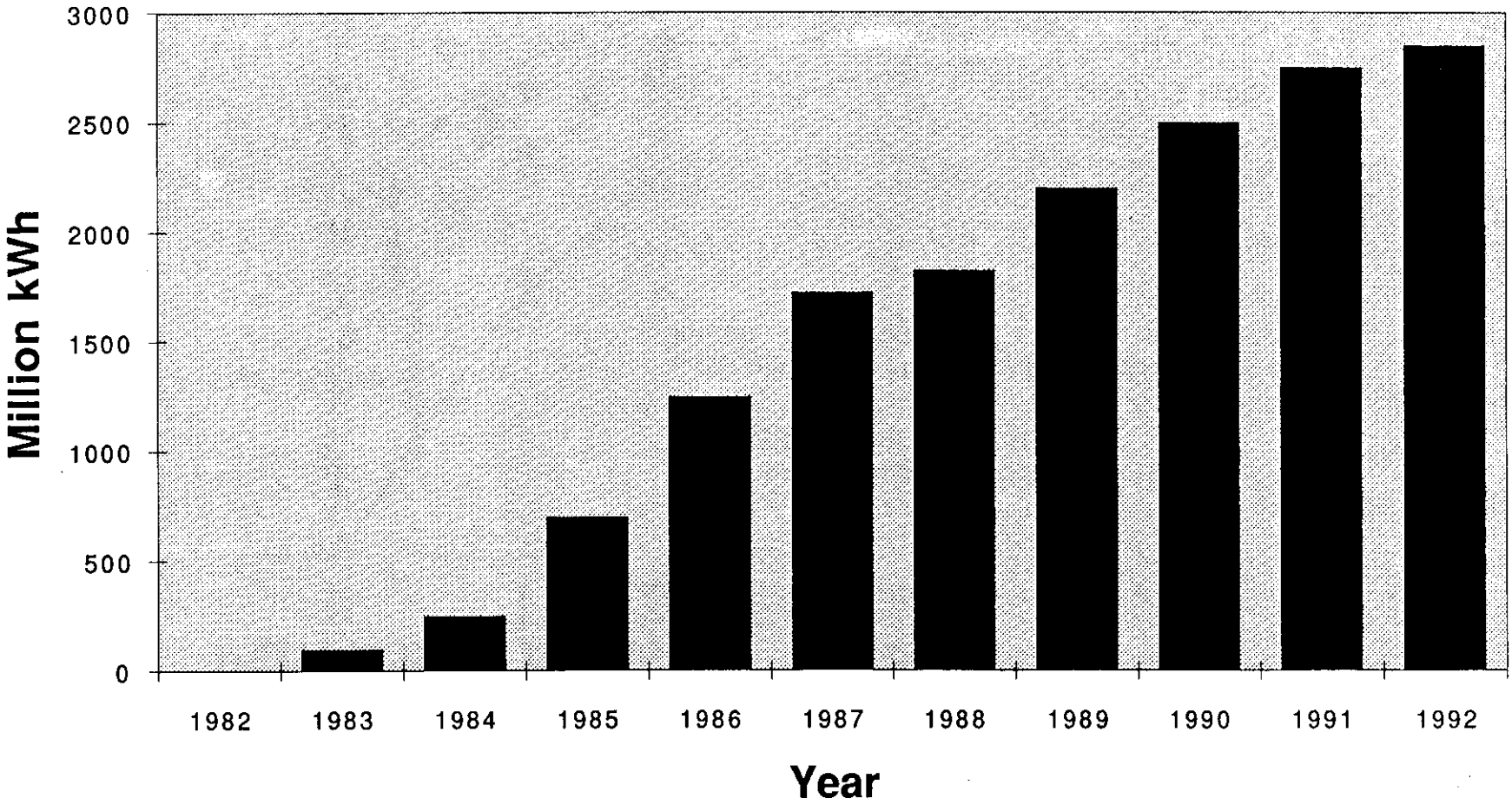
In order to encourage the prosperity of the wind companies currently active in Vermont, services of the Agency of Development and Community Affairs should continue to be made available to assist in the export marketing of these Vermont products. Other steps the State could take to help incubate renewable energy industries include job training support for expanding companies, tax stabilization or investment tax credits for renewable industries, or removal or reduction of capital tax requirements on renewable energy installations.

In order to assist businesses and homeowners wishing to assess the feasibility of installation of a wind machine, the State should investigate an anemometer loan program.

Utilities should develop programs which could install or help customers to finance renewable energy systems on their premises. The State, through its industrial development authority or other means should investigate programs which could help finance installation of wind and other renewable energy systems as well.

FIGURE 1

Wind Generation in California

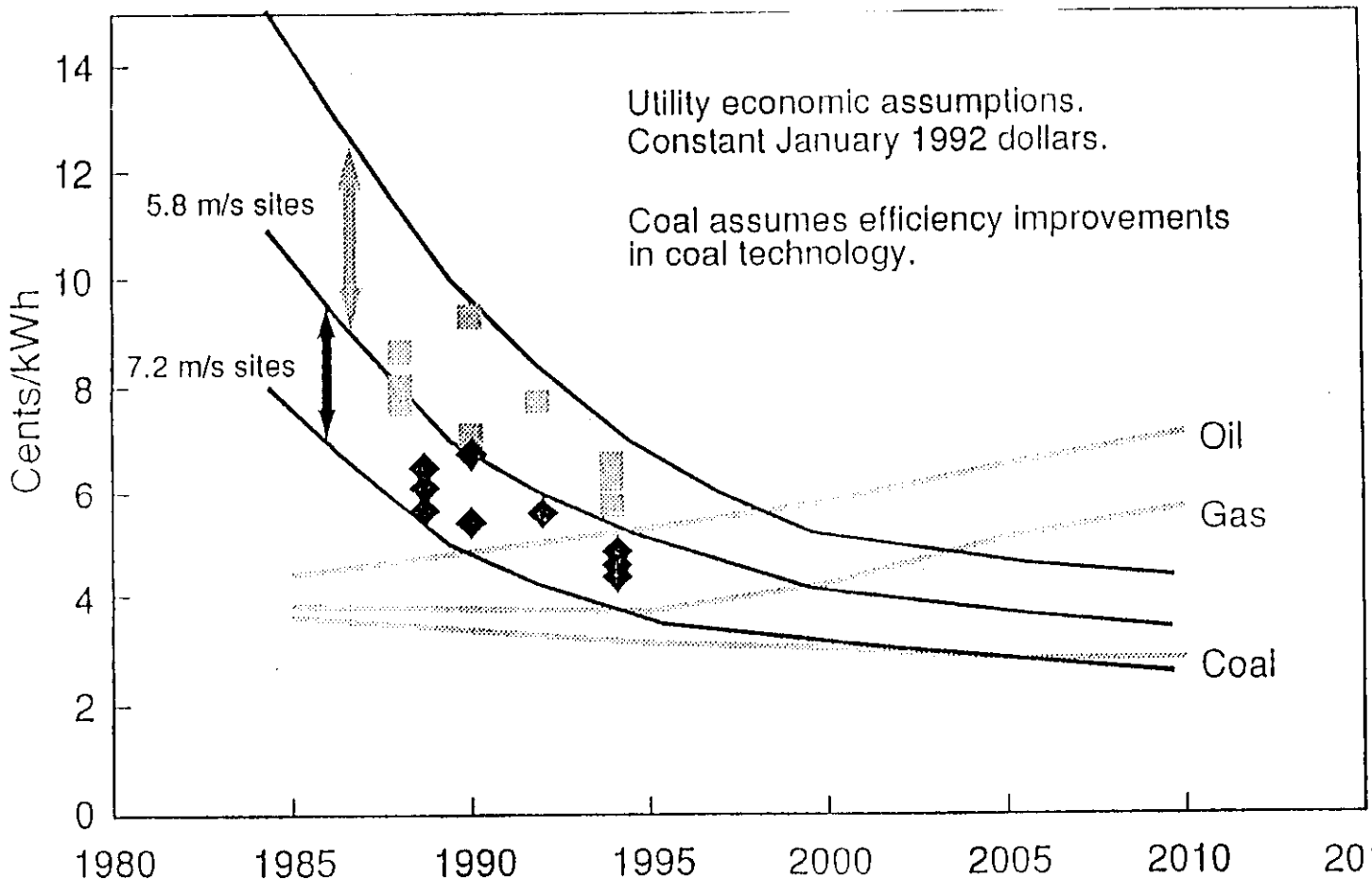


Source: National Renewable Energy Laboratory - NREL

NREL

FIGURE 2

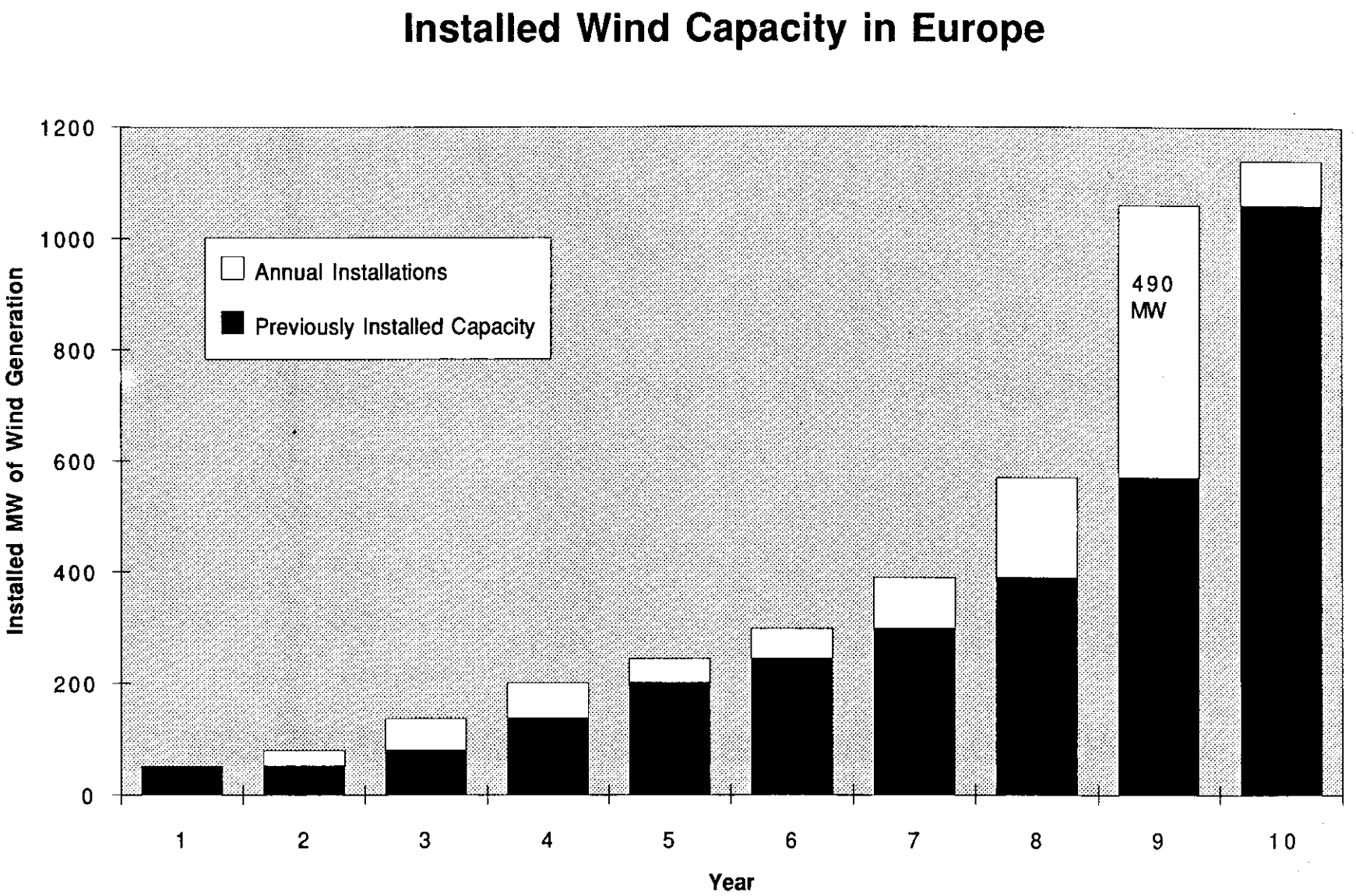
COST OF ENERGY ESTIMATES FOR HORIZONTAL AXIS WIND TURBINES



Source:"Technology Evolution for Wind Energy Technology (draft)", U.S. DOE, June 7, 1993

LS-CD12-b) 120402

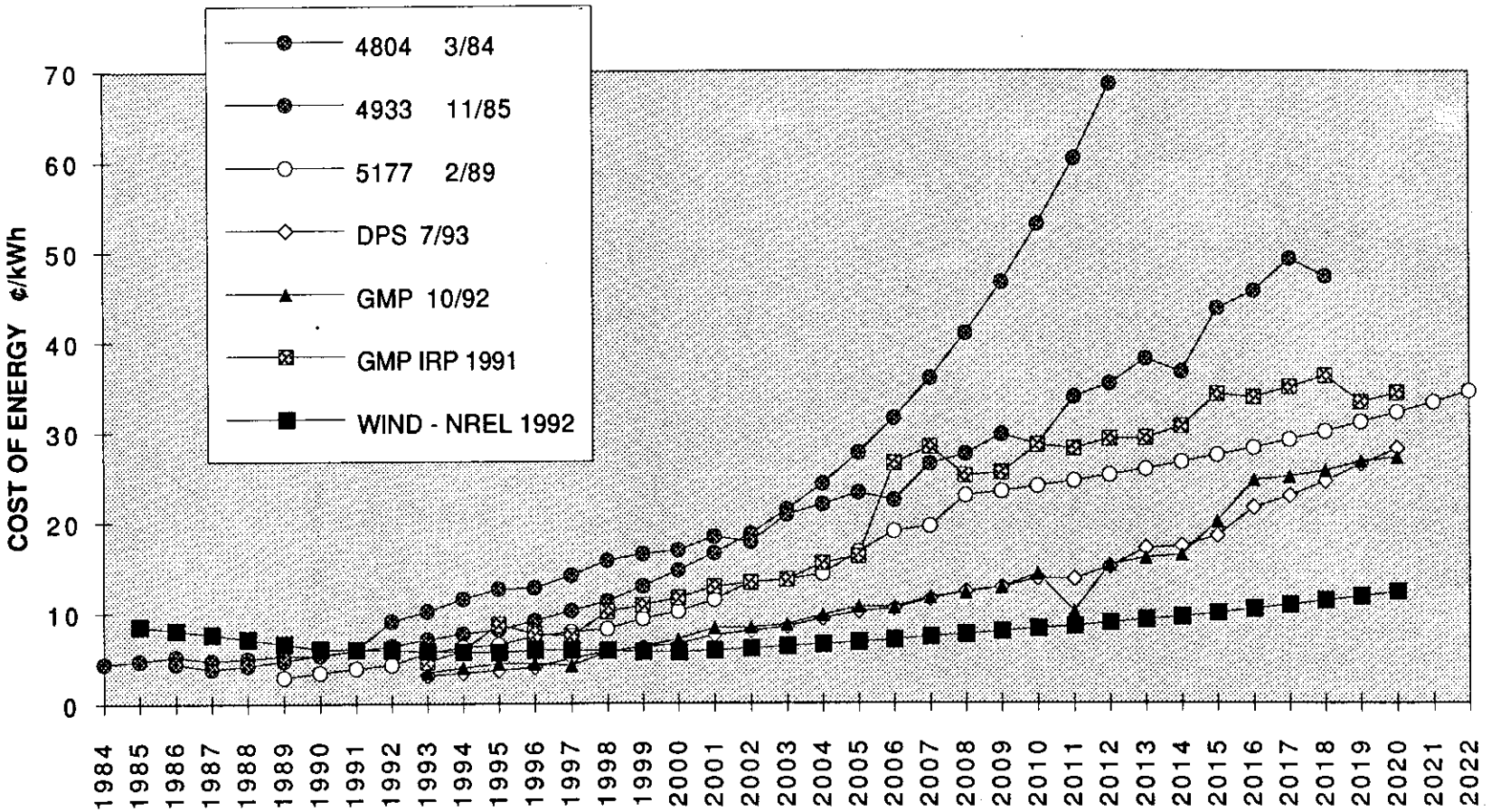
FIGURE 3



Source: National Renewable Energy Laboratory - NREL

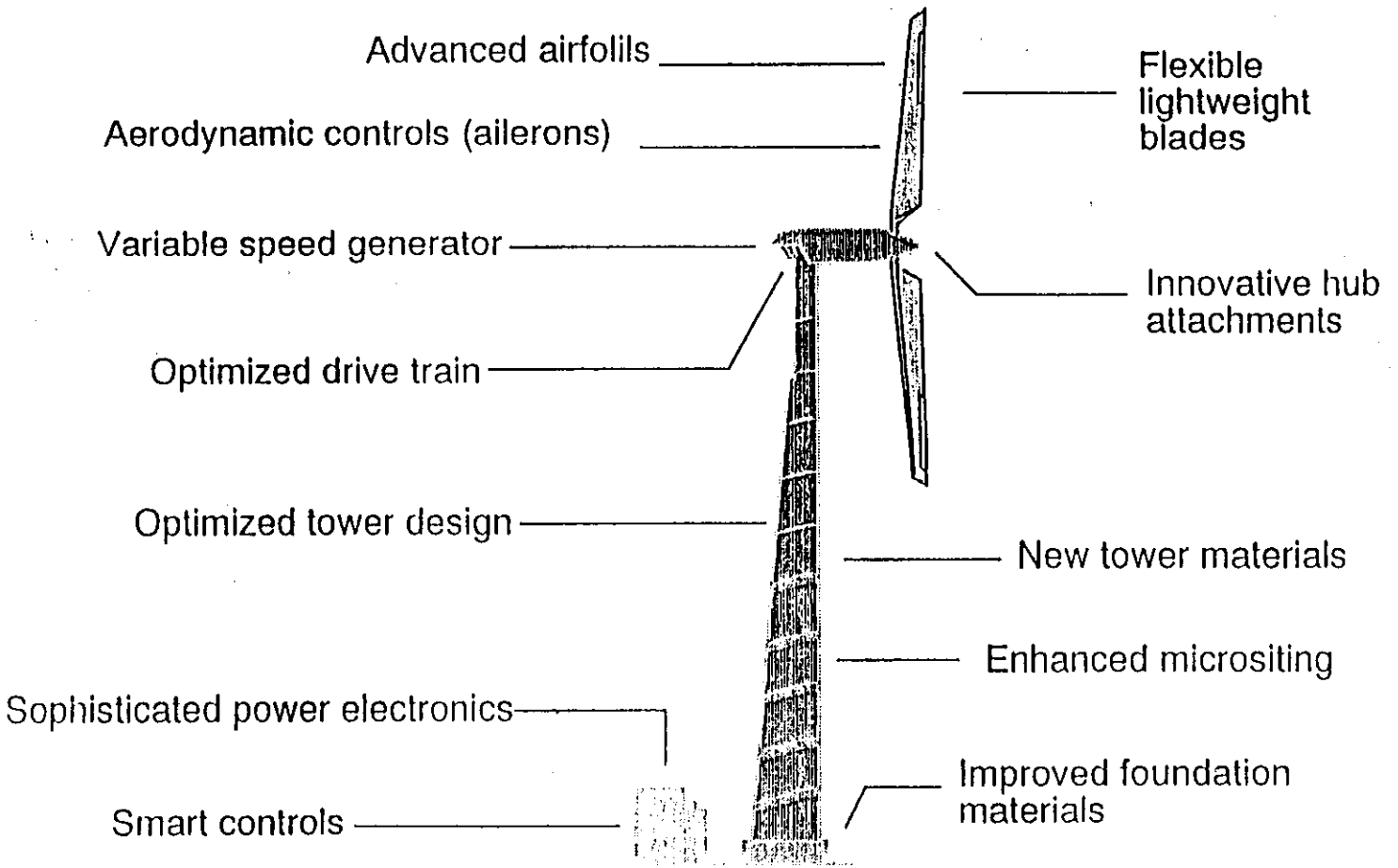
FIGURE 4

COMPARISON OF PROJECTED WIND ENERGY COSTS AND RECENT AVOIDED COST ESTIMATES FOR VERMONT



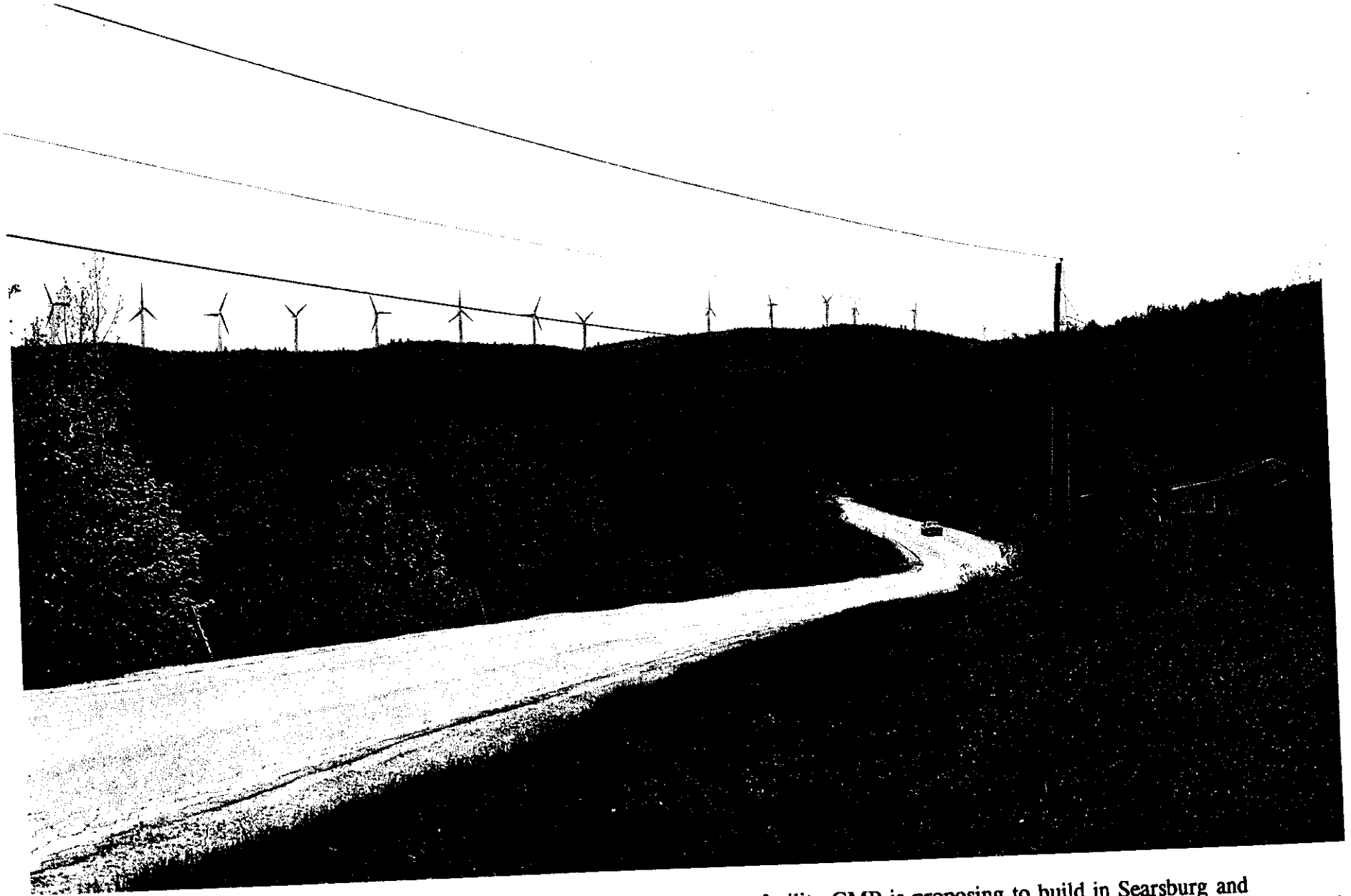
The Advanced Wind Turbine Concept

An artist's rendition of proposed turbine enhancements



P96-G0977519

FIGURE 6



Computer assisted drawing of the northern portion of a wind power facility GMP is proposing to build in Searsburg and Readsboro Vermont. View is looking SSE from along state route 8, 1 1/2 - 2 miles away from the turbines. Illustrated is a representative grouping of the type and size of turbines (250 - 500 kiloWatt each) that may be used in the project.